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Naganuma et al.

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(54) **FUEL CELL SYSTEM AND METHOD OF OPERATING FUEL CELL SYSTEM**

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PCT Pub. Date: **Jan. 13, 2011**

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H01M 8/04 (2016.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC H01M 8/04
See application file for complete search history.

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(57) **ABSTRACT**

The invention is provided to reliably restore generated voltage that has declined due to clogging of water in a fuel cell stack. A method of operating a fuel cell system having a fuel cell stack that generates electricity through an electrochemical reaction between a fuel gas including hydrogen gas and an oxidation gas, wherein when a generated voltage of the fuel cell stack declines, the water-in-cell content of the fuel cell stack is adjusted so that a variation in cell pressure loss in the fuel cell stack decreases based on a characteristic curve of the water-in-cell content of the fuel cell stack and the cell pressure loss of the fuel cell stack.

5 Claims, 10 Drawing Sheets

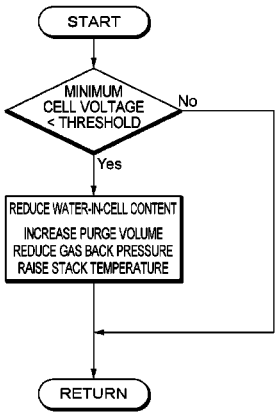


Fig. 1

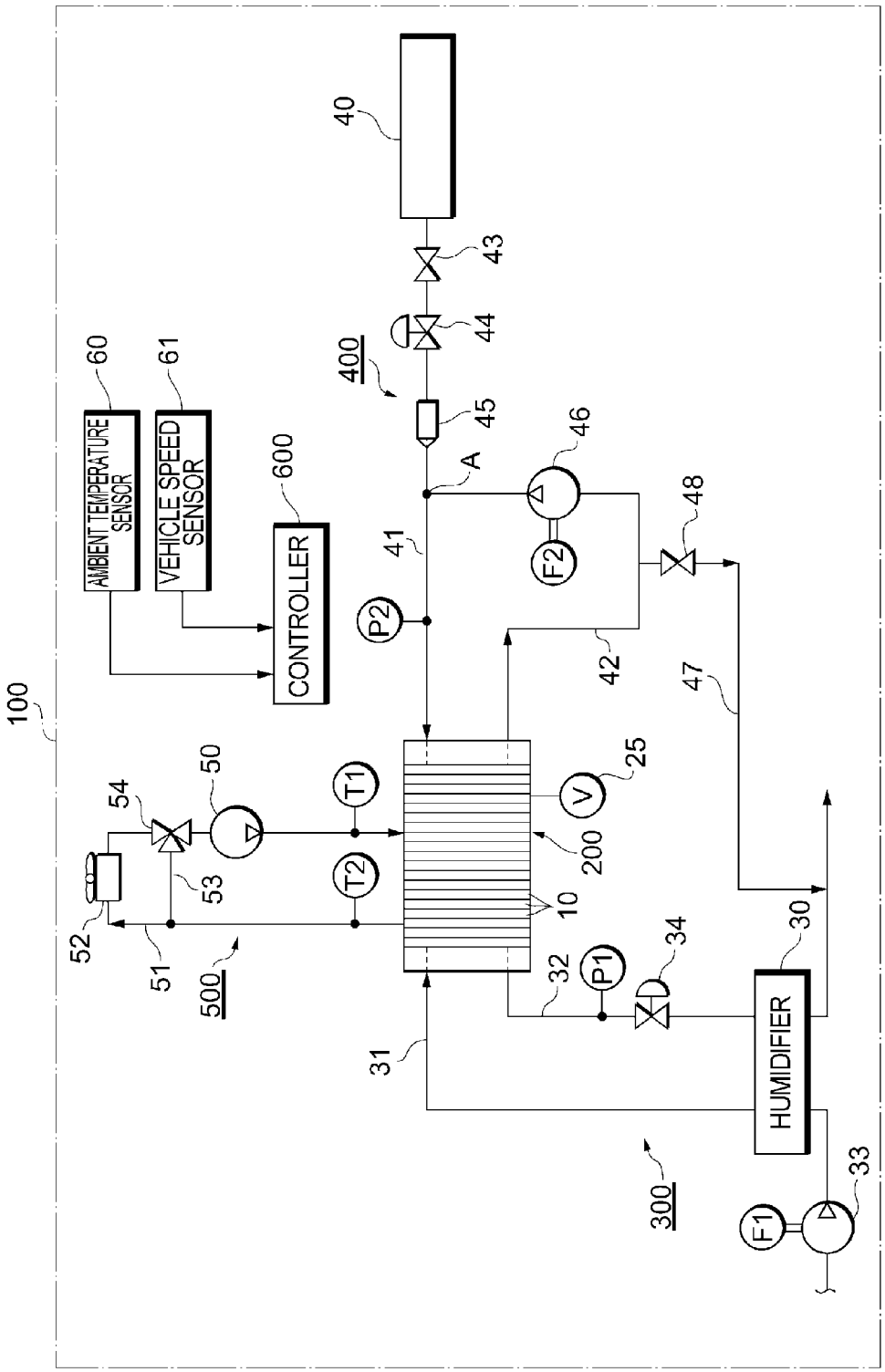

100
40
43
44
400
45
A
46
48
60
61
AMBIENT TEMPERATURE SENSOR
VEHICLE SPEED SENSOR
600
CONTROLLER
41
P2
F2
42
47
50
54
T1
T2
25
V
200
10
53
52
51
500
32
P1
34
30
31
HUMIDIFIER
300
F1
33

Fig. 2

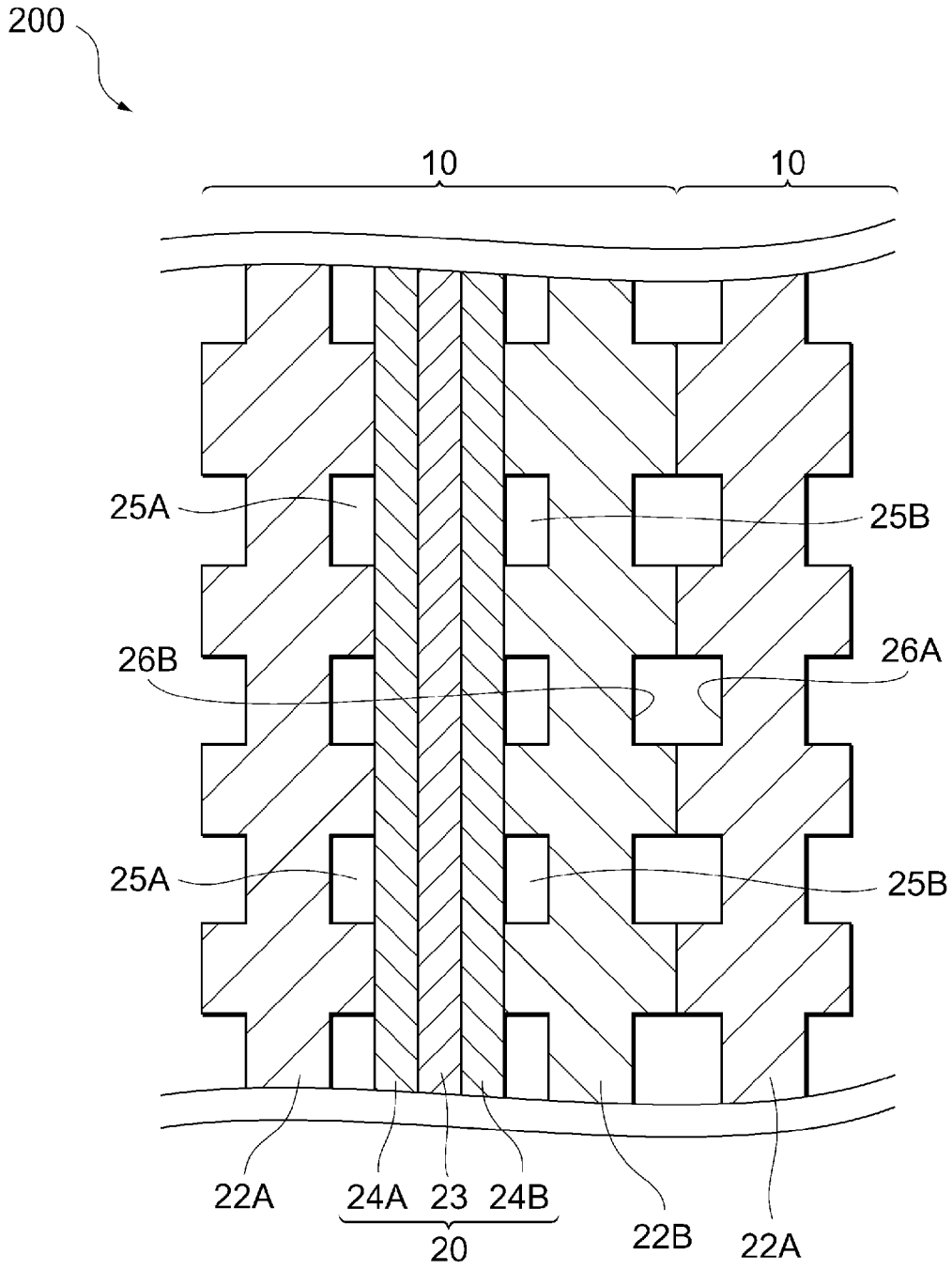


Fig. 3

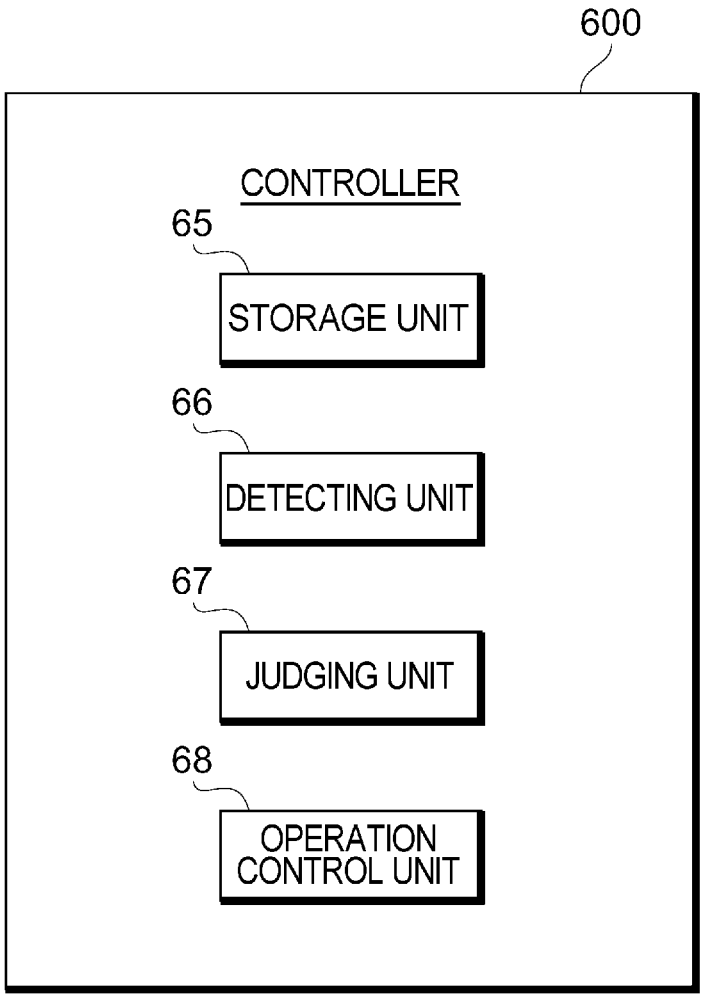
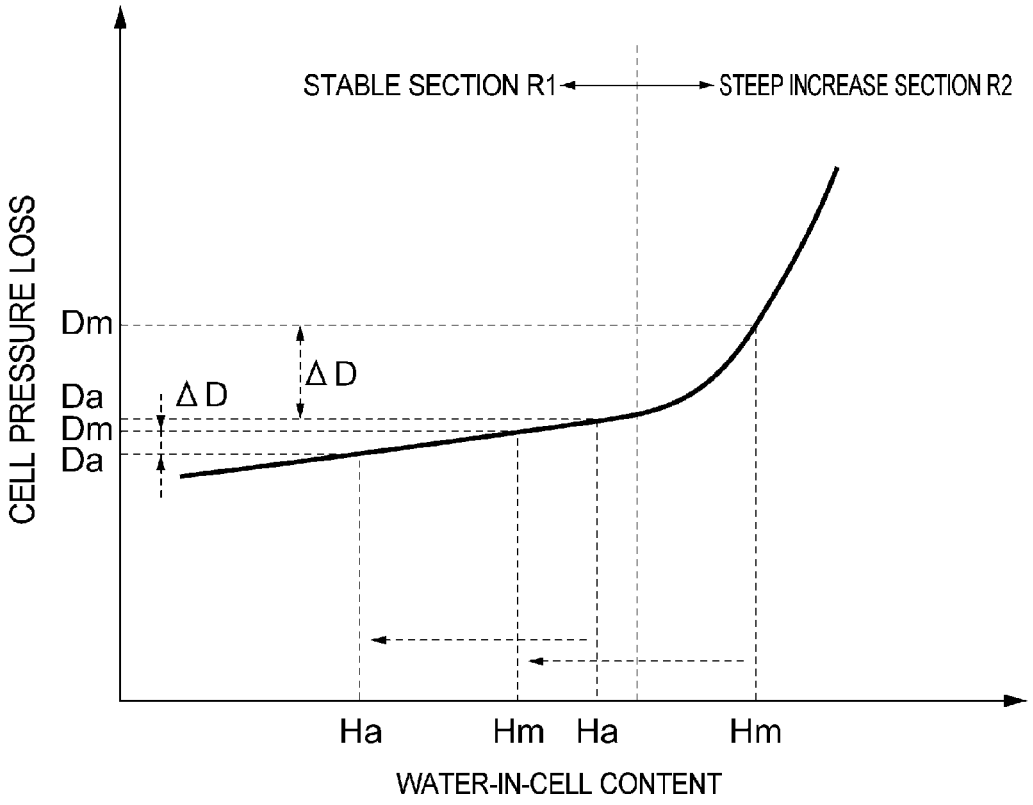

600
CONTROLLER
65
STORAGE UNIT
66
DETECTING UNIT
67
JUDGING UNIT
68
OPERATION CONTROL UNIT

Fig. 4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STEEP INCREASE SECTION R2
CELL PRESSURE LOSS
Dm
Da
Dm
Da
ΔD
ΔD
Ha
Hm
Ha
Hm
WATER-IN-CELL CONTENT

Fig. 5

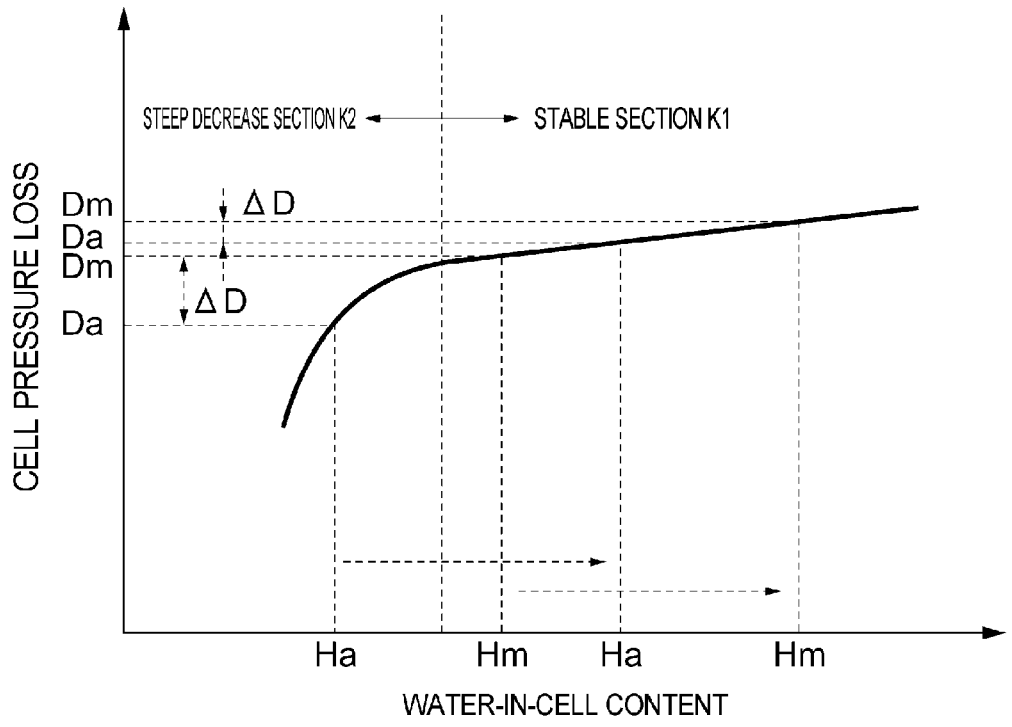

STEEP DECREASE SECTION K2
STABLE SECTION K1
CELL PRESSURE LOSS
Dm
Da
Dm
Da
ΔD
ΔD
Ha
Hm
Ha
Hm
WATER-IN-CELL CONTENT

Fig. 6

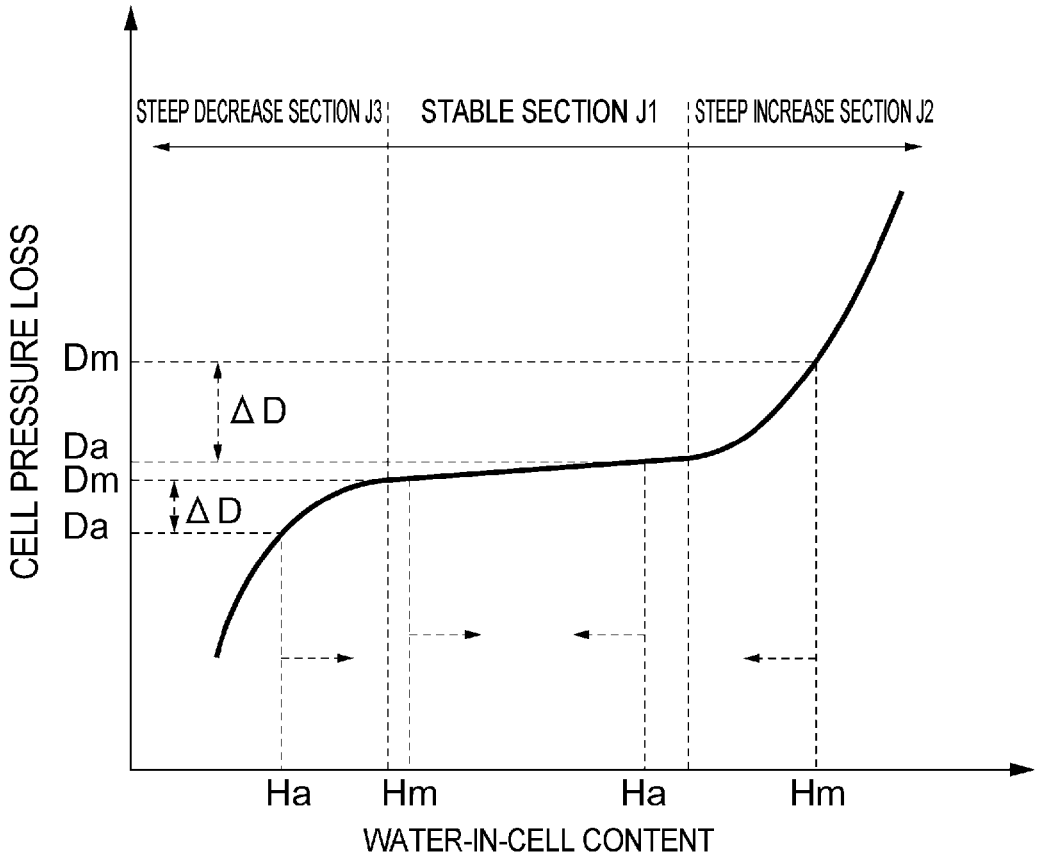

STEEP DECREASE SECTION J3
STABLE SECTION J1
STEEP INCREASE SECTION J2
CELL PRESSURE LOSS
Dm
ΔD
Da
Dm
ΔD
Da
Ha
Hm
Ha
Hm
WATER-IN-CELL CONTENT

Fig. 7

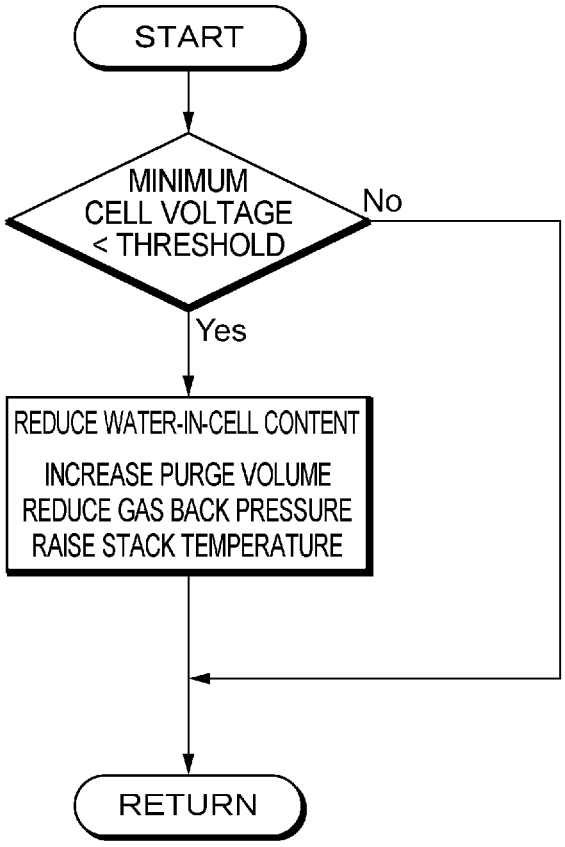

START
MINIMUM CELL VOLTAGE < THRESHOLD
No
Yes
REDUCE WATER-IN-CELL CONTENT
INCREASE PURGE VOLUME
REDUCE GAS BACK PRESSURE
RAISE STACK TEMPERATURE
RETURN

Fig. 8

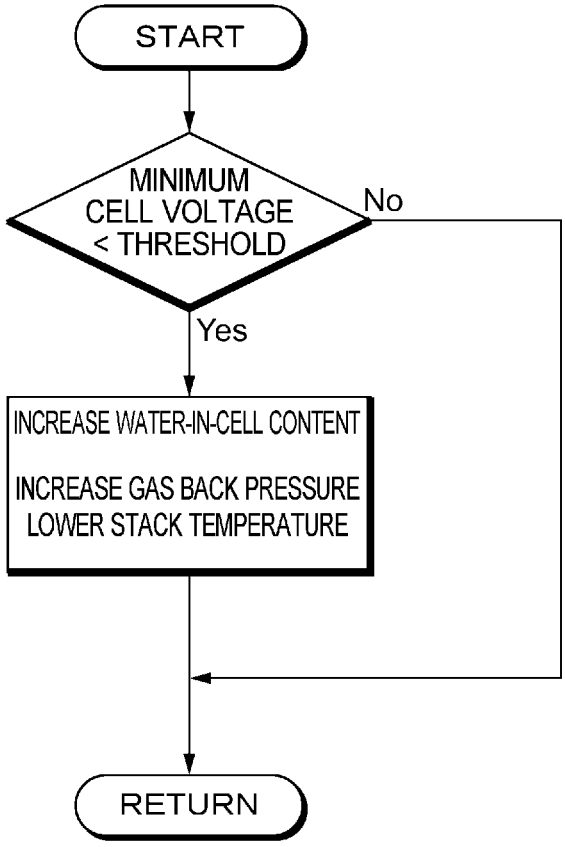

START
MINIMUM CELL VOLTAGE < THRESHOLD
No
Yes
INCREASE WATER-IN-CELL CONTENT
INCREASE GAS BACK PRESSURE
LOWER STACK TEMPERATURE
RETURN

Fig. 9

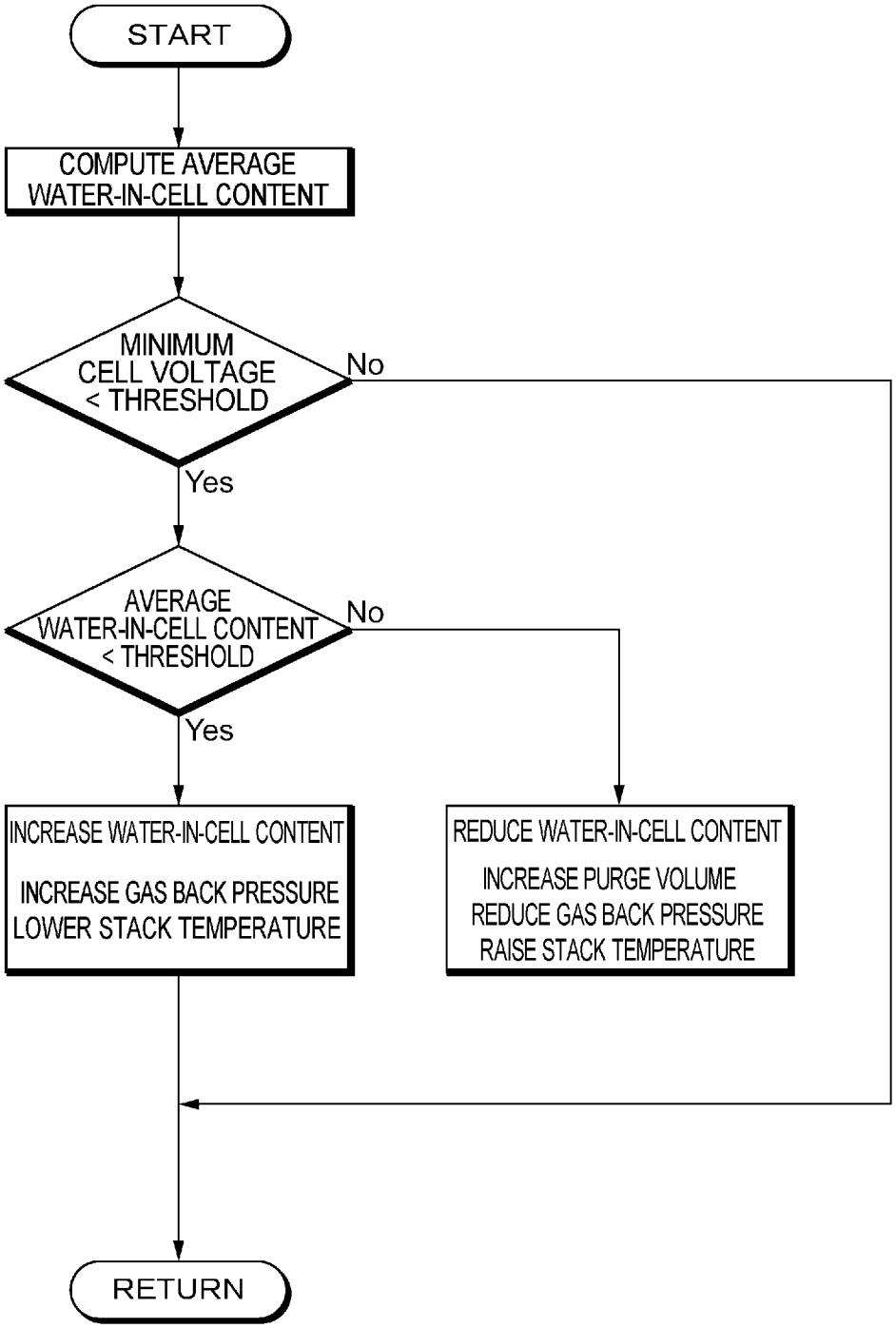
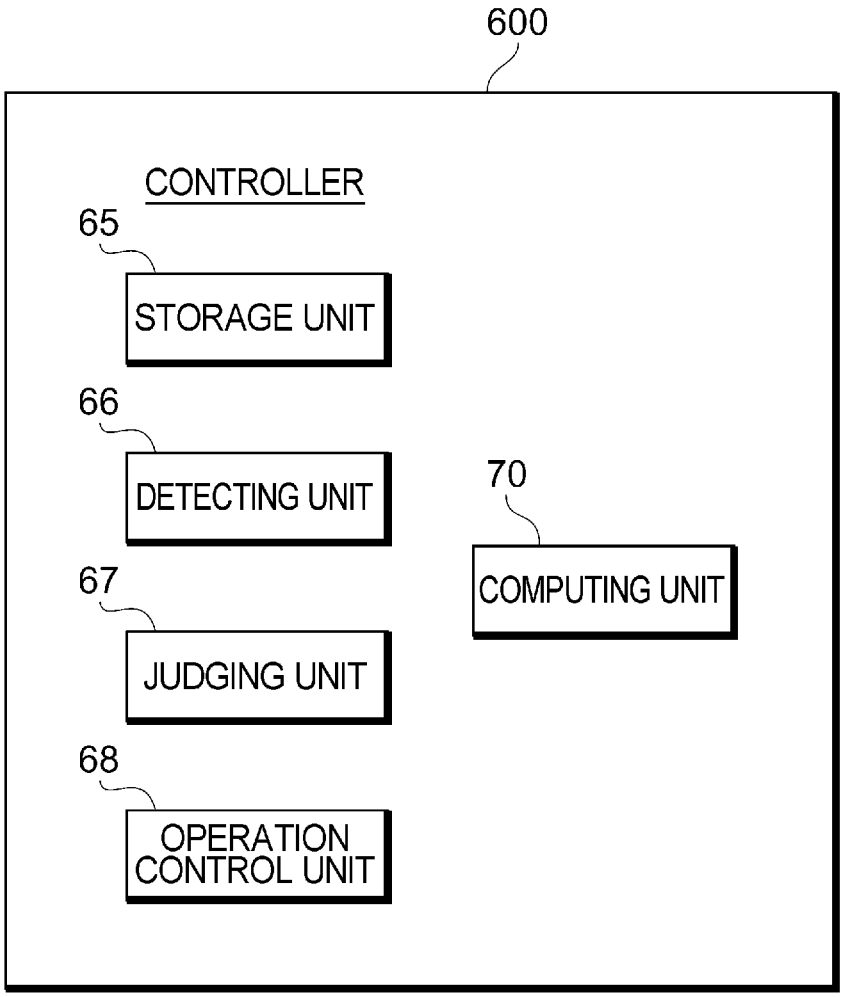

START
COMPUTE AVERAGE WATER-IN-CELL CONTENT
MINIMUM CELL VOLTAGE < THRESHOLD
No
Yes
AVERAGE WATER-IN-CELL CONTENT < THRESHOLD
No
Yes
INCREASE WATER-IN-CELL CONTENT
INCREASE GAS BACK PRESSURE
LOWER STACK TEMPERATURE
REDUCE WATER-IN-CELL CONTENT
INCREASE PURGE VOLUME
REDUCE GAS BACK PRESSURE
RAISE STACK TEMPERATURE
RETURN

Fig. 10


600
CONTROLLER
65
STORAGE UNIT
66
DETECTING UNIT
67
JUDGING UNIT
68
OPERATION CONTROL UNIT
70
COMPUTING UNIT

FUEL CELL SYSTEM AND METHOD OF OPERATING FUEL CELL SYSTEM

This is a 371 national phase application of PCT/JP2009/062539 filed 9 Jul. 2009, the contents of which are incorporated herein by reference.

The present invention relates to a fuel cell system and a method of operating a fuel cell system.

BACKGROUND ART

For example, a fuel cell system mounted to a vehicle such as an automobile as a drive source comprises a fuel cell that generates electricity through an electrochemical reaction between a fuel gas including hydrogen gas and an oxidation gas. The fuel cell has a stack structure in which a plurality of cells is laminated.

During an operation of the fuel cell system, for example, a portion of water produced by an electrochemical reaction in the fuel cell stack penetrates into a cell. When a water content in the cell increases excessively and the cell becomes clogged by water, there may be cases where gas is unable to travel through the cell and a gas supply deviates from stoichiometry, resulting in a decrease in generated voltage.

Therefore, clogging of water in a cell of a fuel cell stack is detected and the detected water in the cell is discharged by increasing a purge volume (refer to Patent Document 1).

Patent document 1: Patent Publication JP-A-2002-260704

Patent document 2: Patent Publication JP-A-2005-63712

Patent document 3: Patent Publication JP-A-2007-184136

Patent document 4: Patent Publication JP-A-2003-217624

However, there may be cases where simply increasing a purge volume as described above does not restore generated voltage. This is conceivably due to the fact that purging and reducing water content may result in a greater variation in cell pressure loss among cells in a fuel cell stack, in which case gas is not sufficiently supplied to a cell with a greatest relative pressure loss and electricity is not generated efficiently.

SUMMARY

The present invention has been made in consideration of the above, and an object thereof is to provide a fuel cell system and a method of operating a fuel cell system capable of reliably restoring generated voltage that has declined due to clogging of water in a fuel cell stack.

In order to achieve the object described above, the present invention is a fuel cell system having a fuel cell stack that generates electricity through an electrochemical reaction between a fuel gas including hydrogen gas and an oxidation gas, the fuel cell system having water-in-cell content adjusting means for adjusting, when a generated voltage of the fuel cell stack declines, a water-in-cell content of the fuel cell stack so that a variation in cell pressure loss in the fuel cell stack decreases based on a characteristic curve of the water-in-cell content of the fuel cell stack and the cell pressure loss of the fuel cell stack. Moreover, a decline in the generated voltage of the fuel cell stack is not limited to a decline in a generated voltage of an entire fuel cell stack and also includes a decline in a generated voltage of each cell in the fuel cell stack.

According to the present invention, since a variation in the cell pressure loss in the fuel cell stack can be reduced, gas can be supplied in a proper amount of gas supply stoichiometry to all cells in the fuel cell stack and, as a result, generated voltage can be reliably restored.

In a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack increases relatively moderately, to a steep increase section, in which the cell pressure loss of the fuel cell stack increases relatively steeply, with respect to an increase in the water-in-cell content of the fuel cell stack, the water-in-cell content adjusting means may adjust the water-in-cell content of the fuel cell stack to be decreased when the generated voltage of the fuel cell stack declines. In such a case, the water-in-cell content of the fuel cell stack can be reduced to restore the cell pressure loss of each cell in the fuel cell stack to the stable section. Consequently, a variation in the cell pressure loss in the fuel cell stack can be reduced and generated voltage can be restored.

In a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack decreases relatively moderately, to a steep decrease section, in which the cell pressure loss of the fuel cell stack decreases relatively steeply, with respect to a decrease in the water-in-cell content of the fuel cell stack, the water-in-cell content adjusting means may adjust the water-in-cell content of the fuel cell stack is adjusted to increase when the generated voltage of the fuel cell stack declines. In such a case, the water-in-cell content of the fuel cell stack can be increased to restore the cell pressure loss of each cell in the fuel cell stack to the stable section. Consequently, a variation in the cell pressure loss in the fuel cell stack can be reduced and generated voltage can be restored.

In a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack increases relatively moderately, to a steep increase section, in which the cell pressure loss of the fuel cell stack increases relatively steeply, with respect to an increase in the water-in-cell content of the fuel cell stack and a transition from the stable section, in which the cell pressure loss of the fuel cell stack decreases relatively moderately, to a steep decrease section, in which the cell pressure loss of the fuel cell stack decreases relatively steeply, with respect to a decrease in the water-in-cell content of the fuel cell stack, the water-in-cell content adjusting means may adjust, when the generated voltage of the fuel cell stack declines, the water-in-cell content of the fuel cell stack to be decrease if an average water-in-cell content of the fuel cell stack is in the stable section or the steep increase section and adjust the water-in-cell content of the fuel cell stack to be increased if the average water-in-cell content of the fuel cell stack is in the steep decrease section. In such a case, the water-in-cell content of the fuel cell stack can be reduced or increased to restore the cell pressure loss of each cell in the fuel cell stack to the stable section. Consequently, a variation in the cell pressure loss in the fuel cell stack can be reduced and generated voltage can be restored.

In the fuel cell system described above, the adjustment of the water-in-cell content of the fuel cell stack may be performed by at least any of an adjustment of a purge volume of the fuel cell stack, an adjustment of a gas back pressure of the fuel cell stack, and an adjustment of a temperature of the fuel cell stack.

The present invention according to another aspect is a method of operating a fuel cell system having a fuel cell stack that generates electricity through an electrochemical reaction between a fuel gas including hydrogen gas and an oxidation gas, the method of operating a fuel cell system comprising adjusting, when a generated voltage of the fuel cell stack declines, a water-in-cell content of the fuel cell stack so that a variation in cell pressure loss in the fuel cell stack decreases

based on a characteristic curve of the water-in-cell content of the fuel cell stack and the cell pressure loss of the fuel cell stack.

According to the present invention, since a variation in the cell pressure loss in the fuel cell stack is reduced, gas can be supplied in a proper amount of gas supply stoichiometry to all cells in the fuel cell stack and, as a result, generated voltage can be reliably restored.

In the method of operating the fuel cell system described above, in a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack increases relatively moderately, to a steep increase section, in which the cell pressure loss of the fuel cell stack increases relatively steeply, with respect to an increase in the water-in-cell content of the fuel cell stack, the water-in-cell content of the fuel cell stack may be adjusted to decrease when the generated voltage of the fuel cell stack declines. In such a case, the water-in-cell content of the fuel cell stack can be reduced to restore the cell pressure loss of each cell in the fuel cell stack to the stable section. Consequently, a variation in the cell pressure loss in the fuel cell stack can be reduced and generated voltage can be restored.

In the method of operating the fuel cell system described above, in a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack decreases relatively moderately, to a steep decrease section, in which the cell pressure loss of the fuel cell stack decreases relatively steeply, with respect to a decrease in the water-in-cell content of the fuel cell stack, the water-in-cell content of the fuel cell stack may be adjusted to increase when the generated voltage of the fuel cell stack declines. In such a case, the water-in-cell content of the fuel cell stack can be increased to restore the cell pressure loss of each cell in the fuel cell stack to the stable section. Consequently, a variation in the cell pressure loss in the fuel cell stack can be reduced and generated voltage can be restored.

In the method of operating the fuel cell system described above, in a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack increases relatively moderately, to a steep increase section, in which the cell pressure loss of the fuel cell stack increases relatively steeply, with respect to an increase in the water-in-cell content of the fuel cell stack and a transition from the stable section, in which the cell pressure loss of the fuel cell stack decreases relatively moderately, to a steep decrease section, in which the cell pressure loss of the fuel cell stack decreases relatively steeply, with respect to a decrease in the water-in-cell content of the fuel cell stack, when the generated voltage of the fuel cell stack declines, the water-in-cell content of the fuel cell stack may be adjusted to decrease if an average water-in-cell content of the fuel cell stack is in the stable section or the steep increase section and the water-in-cell content of the fuel cell stack may be adjusted so as to increase if the average water-in-cell content of the fuel cell stack is in the steep decrease section. In such a case, the water-in-cell content of the fuel cell stack can be reduced or increased to restore the cell pressure loss of each cell in the fuel cell stack to the stable section. Consequently, a variation in the cell pressure loss in the fuel cell stack can be reduced and generated voltage can be restored.

The adjustment of the water content of the fuel cell stack may be performed by at least any of an adjustment of a purge volume of the fuel cell stack, an adjustment of a gas back pressure of the fuel cell stack, and an adjustment of a temperature of the fuel cell stack.

According to the present invention, when generated voltage of a fuel cell stack declines due to clogging of water in the fuel cell stack, the generated voltage can be reliably restored.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram showing an outline of a configuration of a fuel cell system;

FIG. **2** is an explanatory diagram of a longitudinal cross section showing a configuration of a cell of a fuel cell stack;

FIG. **3** is a block diagram of a controller;

FIG. **4** is a graph showing a characteristic curve of a pattern **1**;

FIG. **5** is a graph showing a characteristic curve of a pattern **2**;

FIG. **6** is a graph showing a characteristic curve of a pattern **3**;

FIG. **7** is a flow chart of a method of operating a fuel cell system in a case of the characteristic curve of the pattern **1**;

FIG. **8** is a flow chart of a method of operating a fuel cell system in a case of the characteristic curve of the pattern **2**;

FIG. **9** is a flow chart of a method of operating a fuel cell system in a case of the characteristic curve of the pattern **3**; and

FIG. **10** is a block diagram of a controller comprising a computing unit.

DETAILED DESCRIPTION

Hereinafter, a preferred embodiment of the present invention will be described with reference to the drawings. FIG. **1** is a schematic diagram showing an outline of a configuration of a fuel cell system **100** on which a method of operating a fuel cell system according to the present embodiment is performed.

For example, the fuel cell system **100** comprises a fuel cell stack **200**, an air piping system **300**, a hydrogen piping system **400**, a cooling medium piping system **500**, and a controller **600**. The fuel cell system **100** can be mounted on various mobile objects such as a vehicle, a ship, an airplane, and a robot, and can also be applied to a stationary power source. Here, an example of the fuel cell system **100** mounted on an automobile will be described.

The fuel cell stack **200** has a stack structure in which a plurality of polymer electrolyte cells **10** is laminated. As shown in FIG. **2**, the cell **10** comprises an MEA **20** and a pair of separators **22**A and **22**B. The MEA **20** (membrane-electrode assembly) comprises an electrolyte membrane **23** made of an ion-exchange membrane, and an anode electrode **24**A and a cathode electrode **24**B which sandwich the electrolyte membrane **23**. A hydrogen flow channel **25**A of the separator **22**A faces the electrode **24**A and an air flow channel **25**B of the separator **22**B faces the electrode **24**B. In addition, cooling medium flow channels **26**A and **26**B of the separators **22**A and **22**B travel between adjacent single cells **10**. Moreover, the amount of water contained in the cell **10** is considered to be a water-in-cell content of the fuel cell stack **200**. In addition, as shown in FIG. **1**, the fuel cell stack **200** is provided with a voltmeter **25** capable of measuring a generated voltage of each cell of the fuel cell stack **200**.

The air piping system **300** supplies air as an oxidation gas to and discharges air from the fuel cell stack **200**, and comprises a humidifier **30**, a supply flow channel **31**, an exhaust flow channel **32**, and a compressor **33**. Ambient air (air in a low moisture state) is taken in by the compressor **33** and pressure-fed to the humidifier **30**. Moisture exchange between the air and an oxidation offgas in a high moisture

state is performed at the humidifier **30**. As a result, moderately humidified air is supplied from the supply flow channel **31** to the fuel cell stack **200**. A back pressure valve **34** for adjusting an air back pressure of the fuel cell stack **200** is provided in the exhaust flow channel **32**. In addition, a pressure sensor P**1** that detects an air back pressure is provided in a vicinity of the back pressure valve **34**. A flow rate sensor F**1** that detects an air supply flow rate to the fuel cell stack **200** is provided at the compressor **33**.

The hydrogen piping system **400** supplies hydrogen gas as a fuel gas to and discharges hydrogen gas from the fuel cell stack **200**, and comprises a hydrogen supply source **40**, a supply flow channel **41**, a circulation flow channel **42**, a shut valve **43**, a regulator **44**, an injector **45**, and the like. The hydrogen gas from the hydrogen supply source **40** is decompressed by the regulator **44** and is then subjected to high-precision adjustment of a flow rate and pressure by an injector **45**. Subsequently, the hydrogen gas joins a hydrogen offgas pressure-fed by a hydrogen pump **46** as a gas circulator on the circulation flow channel **42** at a confluence A to be supplied to the fuel cell stack **200**. A purge channel **47** including a purge valve **48** is branched and connected to the circulation flow channel **42**. By opening the purge valve **48**, a hydrogen offgas is discharged to the exhaust flow channel **32**. A pressure sensor P**2** that detects a supply pressure of hydrogen gas to the fuel cell stack **200** is provided downstream of the confluence A of the supply flow channel **41**. In addition, a flow rate sensor F**2** is provided at the hydrogen pump **46**. Moreover, in other embodiments, a fuel offgas may be introduced into a hydrogen diluter or the like or a gas-liquid separator may be provided in the circulation flow channel **42**.

The cooling medium piping system **500** circulates and supplies a cooling medium (for example, cooling water) to the fuel cell stack **200**, and comprises a cooling pump **50**, a cooling medium flow channel **51**, a radiator **52**, a bypass flow channel **53**, and a changeover valve **54**. The cooling pump **50** pressure-feeds a cooling medium in the cooling medium flow channel **51** into the fuel cell stack **200**. The cooling medium flow channel **51** comprises a temperature sensor T**1** positioned at a cooling medium inlet of the fuel cell stack **200** and a temperature sensor T**2** positioned at a cooling medium outlet of the fuel cell stack **200**. The radiator **52** cools a cooling medium discharged from the fuel cell stack **200**. The changeover valve **54** comprises a rotary valve or the like and, when necessary, switches over conduction of the cooling medium between the radiator **52** and the bypass flow channel **53**.

The controller **600** is configured as a microcomputer internally comprising a CPU, a ROM, and a RAM. Information detected by the sensors (P**1**, P**2**, F**1**, F**2**, T**1**, and T**2**) which detect pressure, a temperature, a flow rate, and the like of fluids flowing through the respective piping systems **300**, **400**, and **500** is inputted to the controller **600**. Furthermore, in addition to information detected by the voltmeter **25** that measures a generated voltage of each cell in the fuel cell stack **200**, information detected by an ambient temperature sensor **60**, a vehicle speed sensor **61**, an accelerator opening sensor, and the like is inputted to the controller **600**. In accordance with the detected information and the like, the controller **600** controls the various devices (the compressor **33**, the shut valve **43**, the injector **45**, the hydrogen pump **46**, the purge valve **48**, the cooling pump **50**, the changeover valve **54**, and the like) in the fuel cell system **100** and integrally controls operations of the fuel cell system **100**. In addition, the controller **600** reads various types of detected information and adjusts a water-in-cell content of the fuel cell stack **200** using information on a characteristic curve P (to be described later) stored in the ROM.

As shown in FIG. **3**, the controller **600** comprises a storage unit **65**, a detecting unit **66**, a judging unit **67**, and an operation control unit **68** as function blocks for adjusting a water-in-cell content of the fuel cell stack **200**. The storage unit **65** stores various programs for adjusting the water-in-cell content of the fuel cell stack **200** and information on the characteristic curve P. The detecting unit **66** reads information detected by various sensors (P**1**, P**2**, F**1**, F**2**, T**1**, T**2**, **25**, **60**, and **61**) and the like. The judging unit **67** judges, for example, whether or not a minimum cell generated voltage of the cell **10** of the fuel cell stack **200** has dropped below a threshold set in advance. Based on a judgment result by the judging unit **67**, the operation control unit **68** transmits a control order to each device and controls operations so that the fuel cell stack **200** achieves a desired water content.

Based on a judgment made by the judging unit **67**, the operation control unit **68** adjusts a water-in-cell content of the fuel cell stack **200** using information on the characteristic curve P stored in the storage unit **65**. Specifically, a water-in-cell content is adjusted by: an adjustment of a purge volume of the fuel cell stack **200** performed by adjusting an amount of offgas supplied by the hydrogen pump **46** shown in FIG. **1**, adjusting an amount of hydrogen gas supplied by the injector **45**, adjusting an amount of air supplied by the compressor **33**, or the like; an adjustment of a gas back pressure of the fuel cell stack **200** performed by adjusting the back pressure valve **34** or the like; an adjustment of a temperature of the fuel cell stack **200** by controlling a cooling medium temperature of the cooling medium piping system **500**, and the like. Moreover, in the present embodiment, the water-in-cell content adjusting means comprises at least any of the hydrogen pump **46**, the injector **45**, the compressor **33**, the back pressure valve **34**, and the cooling medium piping system **500**, and the controller **600**.

Next, a description will be given of a method of operating the fuel cell system **100** configured as described above.

During an operation of the fuel cell system **100**, there may be cases where water produced by an electrochemical reaction between hydrogen gas and air accumulates excessively in the cell **10** of the fuel cell stack **200**, and as clogging of water occurs, a gas supply deviates from stoichiometry and causes a decline in generated voltage

In the method of operating the fuel cell system **100** according to the present embodiment, when a generated voltage of the fuel cell stack **200** declines, the generated voltage is restored by adjusting the water-in-cell content of the fuel cell stack **200** so that a variation in cell pressure loss in the fuel cell stack **200** decreases based on a characteristic curve P of the water-in-cell content of the fuel cell stack **200** and the cell pressure loss of the fuel cell stack **200**. In this case, cell pressure loss refers to a pressure loss with respect to supply gas at each cell.

The characteristic curve P has three patterns. As shown in FIG. **4**, a pattern P**1** of the characteristic curve P represents a transition from a stable section R**1** in which a cell pressure loss of the fuel cell stack **200** increases relatively moderately to a steep increase section R**2** in which the cell pressure loss of the fuel cell stack **200** increases relatively steeply with respect to an increase in the water-in-cell content of the fuel cell stack **200**. As shown in FIG. **5**, a pattern P**2** of the characteristic curve P represents a transition from a stable section K**1** in which a cell pressure loss of the fuel cell stack **200** decreases relatively moderately to a steep decrease section K**2** in which the cell pressure loss of the fuel cell stack

200 decreases relatively steeply with respect to a decrease in the water-in-cell content of the fuel cell stack **200**. As shown in FIG. **6**, a pattern P**3** of the characteristic curve P represents a transition from a stable section J**1** in which a cell pressure loss of the fuel cell stack **200** increases relatively moderately to a steep increase section J**2** in which the cell pressure loss of the fuel cell stack **200** increases relatively steeply with respect to an increase in the water-in-cell content of the fuel cell stack **200**, and a transition from the stable section J**1** in which the cell pressure loss of the fuel cell stack **200** decreases relatively moderately to a steep decrease section J**3** in which the cell pressure loss of the fuel cell stack **200** decreases relatively steeply with respect to a decrease in the water-in-cell content of the fuel cell stack **200**. Information on the characteristic curves P is obtained in advance by an experiment or the like and is stored in the storage unit **65**.

Hereinafter, a method of operating the fuel cell system **100** with respect to the respective patterns P**1**, P**2**, and P**3** of the characteristic curve P will be specifically described.

First, a case of the pattern P**1** will be described. A flow chart in this case is shown in FIG. **7**. For example, a minimum cell voltage generated by the fuel cell stack **200** is monitored by the voltmeter **25**, and when the minimum cell voltage drops below a predetermined threshold, a water-in-cell content of the fuel cell stack **200** is reduced. A reduction of the water-in-cell content is performed by, for example, increasing a purge volume of the fuel cell stack **200**, reducing a gas back pressure of the fuel cell stack **200**, raising a temperature of the fuel cell stack **200**, and the like. Consequently, as shown in FIG. **4**, for example, since an average water-in-cell content Ha (an average water content of all cells **10**) and a maximum water-in-cell content Hm (a maximum water content among all cells **10**) of the fuel cell stack **200** make transitions from the steep increase section R**2** to the stable section R**1**, a variation in cell pressure loss decreases. In other words, for example, a difference ΔD between an average cell pressure loss Da (an average pressure loss of all cells **10**) and a maximum cell pressure loss Dm (a maximum power loss among all cells **10**) is reduced. Since a gas supply stoichiometry to the fuel cell stack **200** is determined from the average cell pressure loss Da and the maximum cell pressure loss Dm, a decline in the difference ΔD enables a proper amount of gas to be stably supplied to all cells **10**.

Next, a case of the pattern P**2** will be described. A flow chart in this case is shown in FIG. **8**. For example, a minimum cell voltage generated by the fuel cell stack **200** is monitored by the voltmeter **25**, and when the minimum cell voltage drops below a predetermined threshold, a water-in-cell content of the fuel cell stack **200** is increased. An increase of the water-in-cell content is achieved by, for example, increasing a gas back pressure of the fuel cell stack **200**, lowering a temperature of the fuel cell stack **200**, and the like. Consequently, as shown in FIG. **5**, for example, since an average water-in-cell content Ha and a maximum water-in-cell content Hm of the fuel cell stack **200** make transitions from the steep decrease section K**2** to the stable section K**1**, a variation in cell pressure loss decreases. In other words, for example, a difference ΔD between an average cell pressure loss Da and a maximum cell pressure loss Dm is reduced. As described earlier, since a gas supply stoichiometry is determined from the average cell pressure loss Da and the maximum cell pressure loss Dm, a decline in the difference ΔD enables a proper amount of gas to be stably supplied to all cells **10**.

Next, a case of the pattern P**3** will be described. A flow chart in this case is shown in FIG. **9**. First, an average water-in-cell content Ha is calculated. The calculation of the average water-in-cell content Ha is performed by, for example, the computing unit **70** provided in the controller **600** as shown in FIG. **10**. The average water-in-cell content Ha is obtained by measuring a direct-current resistance of the entire fuel cell stack **200** and from a resistance value thereof, or by calculating a water balance of the fuel cell stack **200** from an amount of generated water of the fuel cell stack **200** obtained from a gas supply or an amount of water vapor of a cathode offgas.

In addition, when a minimum cell voltage generated by the fuel cell stack **200** is monitored by the voltmeter **25** and the minimum cell voltage drops below a predetermined threshold, a judgment is made on whether the average water-in-cell content Ha is in the stable section J**1**, the steep increase section J**2**, or the steep decrease section J**3** shown in FIG. **6**. The judgment is performed based on whether or not the average water-in-cell content Ha is higher than a boundary value of the stable section J**1** and the steep decrease section J**3** on the characteristic curve P**3**.

Next, when the average water-in-cell content Ha equals or exceeds the threshold and is in the stable section J**1** or the steep increase section J**2** as shown in FIG. **9**, the water-in-cell content of the fuel cell stack **200** is reduced. A reduction of the water-in-cell content is performed by, for example, increasing a purge volume of the fuel cell stack **200**, reducing a gas back pressure of the fuel cell stack **200**, raising a temperature of the fuel cell stack **200**, and the like. Consequently, as shown in FIG. **6**, for example, since an average water-in-cell content Ha and a maximum water-in-cell content Hm of the fuel cell stack **200** make transitions from the steep increase section J**2** to the stable section J**1**, a variation in cell pressure loss decreases. In other words, for example, a difference ΔD between an average cell pressure loss Da and a maximum cell pressure loss Dm decreases. As described earlier, since a gas supply stoichiometry is determined from the average cell pressure loss Da and the maximum cell pressure loss Dm, a decline in the difference ΔD enables a proper amount of gas to be stably supplied to all cells **10**.

In addition, when the average water-in-cell content Ha is lower than the threshold and is in the steep decrease section J**3** as shown in FIG. **9**, the water-in-cell content of the fuel cell stack **200** is increased. An increase of the water-in-cell content is achieved by, for example, increasing a gas back pressure of the fuel cell stack **200**, lowering a temperature of the fuel cell stack **200**, and the like. Consequently, as shown in FIG. **6**, for example, since an average water-in-cell content Ha and a maximum water-in-cell content Hm of the fuel cell stack **200** make transitions from the steep decrease section J**3** to the stable section J**1**, a variation in cell pressure loss decreases. In other words, for example, a difference ΔD between an average cell pressure loss Da and a maximum cell pressure loss Dm is reduced. As described earlier, since a gas supply stoichiometry is determined from the average cell pressure loss Da and the maximum cell pressure loss Dm, a decline in the difference ΔD enables a proper amount of gas to be stably supplied to all cells **10**.

According to the embodiment described above, since the water-in-cell content of the fuel cell stack **200** is adjusted based on a characteristic curve P of the water-in-cell content of the fuel cell stack **200** and the cell pressure loss of the fuel cell stack **200** and a variation of cell pressure loss in the fuel cell stack **200** is reduced, gas can be supplied in a proper amount of gas supply stoichiometry to all cells **10** in the fuel cell stack **200** and, as a result, generated voltage can be reliably restored.

In addition, in a case where the characteristic curve P is the pattern P**1**, since an adjustment is performed so as to reduce the water-in-cell content of the fuel cell stack **200**, the cell pressure loss of the fuel cell stack **200** can be restored to the

stable section R1. Consequently, a variation in the cell pressure loss in the fuel cell stack **200** can be reduced and generated voltage can be restored.

Furthermore, in a case where the characteristic curve P is the pattern P2, an adjustment is performed so as to increase the water-in-cell content of the fuel cell stack **200** and the cell pressure loss of the fuel cell stack **200** can be restored to the stable section K1. Consequently, a variation in the cell pressure loss in the fuel cell stack **200** can be reduced and generated voltage can be restored.

Moreover, in a case where the characteristic curve P is the pattern P3, a judgment is made on whether the average water-in-cell content Ha of the fuel cell stack **200** is in the stable section J1, the steep increase section J2, or the steep decrease section J3, and depending on the judgment, the water-in-cell content of the fuel cell stack **200** is reduced or increased and the cell pressure loss of the fuel cell stack **200** can be restored to the stable section J1. Consequently, a variation in the cell pressure loss in the fuel cell stack **200** can be reduced and generated voltage can be restored.

Since the adjustment of the water-in-cell content of the fuel cell stack **200** is performed by at least any of an adjustment of a purge volume of the fuel cell stack **200**, an adjustment of a gas back pressure of the fuel cell stack **200**, and an adjustment of a temperature of the fuel cell stack **200**, the water-in-cell content can be adjusted in an easy and proper manner.

While a preferred embodiment of the present invention has been described with reference to the drawings, the present invention is not limited to such an example. It will be obvious to those skilled in the art that various changes and modifications may be made without departing from the spirit and the scope of the invention as hereinafter claimed. It is to be understood that all such changes and modifications also belong to the technical scope of the present invention.

INDUSTRIAL APPLICABILITY

The present invention is useful for reliably restoring generated voltage that has declined due to clogging of water in a fuel cell stack.

EXPLANATION OF REFERENCE NUMERALS

10 cell
100 fuel cell system
200 fuel cell stack
600 controller

We claim:

1. A fuel cell system having a fuel cell stack that generates electricity through an electrochemical reaction between a fuel gas including hydrogen gas and an oxidation gas,

the fuel cell system comprising:

a water-in-cell content adjusting device programmed to adjust, when a generated voltage of the fuel cell stack declines, a water-in-cell content of the fuel cell stack based on a characteristic curve of the water-in-cell content of the fuel cell stack and the cell pressure loss of the fuel cell stack, wherein

the water-in-cell content adjusting device programmed to adjust the water-in-cell content of the fuel cell stack so that an average water-in-cell content of the fuel cell stack falls within a stable section in which the cell pressure loss varies moderately relative to a steep section with respect to the water-in-cell content on the characteristic curve.

2. The fuel cell system according to claim **1**, wherein in a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack increases relatively moderately, to a steep increase section, in which the cell pressure loss of the fuel cell stack increases relatively steeply, with respect to an increase in the water-in-cell content of the fuel cell stack, the water-in-cell content adjusting device programmed to adjust the water-in-cell content of the fuel cell stack to be decreased when the generated voltage of the fuel cell stack declines.

3. The fuel cell system according to claim **1**, wherein in a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack decreases relatively moderately, to a steep decrease section, in which the cell pressure loss of the fuel cell stack decreases relatively steeply, with respect to a decrease in the water-in-cell content of the fuel cell stack, the water-in-cell content adjusting device programmed to adjust the water-in-cell content of the fuel cell stack to be increased when the generated voltage of the fuel cell stack declines.

4. The fuel cell system according to claim **1**, wherein in a case where the characteristic curve includes a transition from a stable section, in which the cell pressure loss of the fuel cell stack increases relatively moderately to a steep increase section, in which the cell pressure loss of the fuel cell stack increases relatively steeply, with respect to an increase in the water-in-cell content of the fuel cell stack and a transition from the stable section, in which the cell pressure loss of the fuel cell stack decreases relatively moderately to a steep decrease section, in which the cell pressure loss of the fuel cell stack decreases relatively steeply, with respect to a decrease in the water-in-cell content of the fuel cell stack, the water-in-cell content adjusting device adjusts, when the generated voltage of the fuel cell stack declines, the water-in-cell content of the fuel cell stack to be decreased if an average water-in-cell content of the fuel cell stack is in the stable section or the steep increase section and the water-in-cell content of the fuel cell stack is adjusted to increase if the average water-in-cell content of the fuel cell stack is in the steep decrease section.

5. The fuel cell system according to claim **1**, wherein the adjustment of the water-in-cell content of the fuel cell stack is performed by at least one of the following: an adjustment of a purge volume of the fuel cell stack, an adjustment of a gas back pressure of the fuel cell stack, and an adjustment of a temperature of the fuel cell stack.

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